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(54) SMART TRANSPARENCY FOR VIRTUAL OBJECTS

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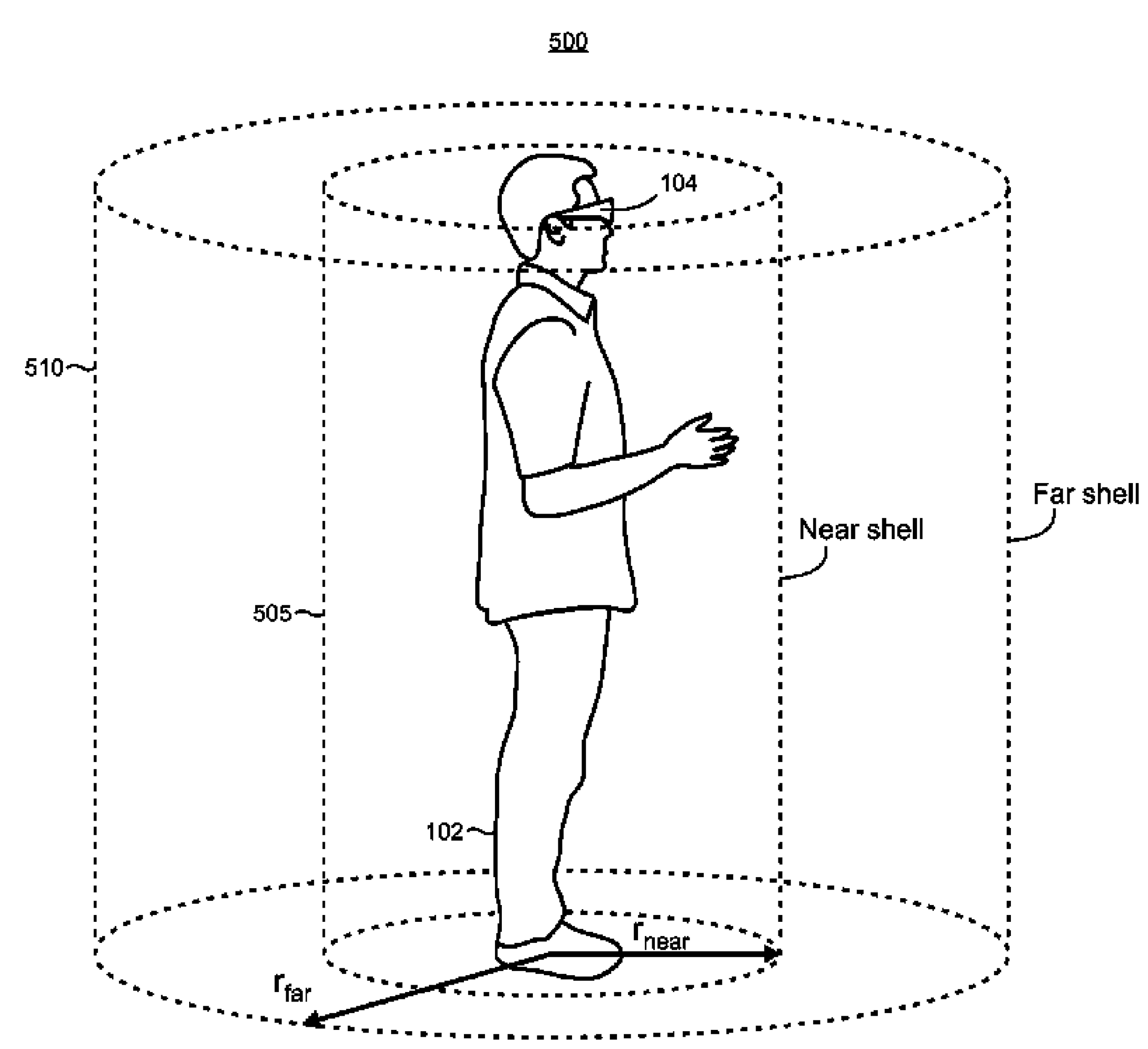
(57) **ABSTRACT**

A head mounted display (HMD) device is configured with a sensor package that enables head tracking to determine the device user's proximity to virtual objects in a mixed reality or virtual reality environment. A fade volume including concentrically-arranged volumetric shells is placed around the user including a near shell that is closest to the user, and a far shell that is farthest from the user. When a virtual object is beyond the far shell, the HMD device renders the object with full opacity (i.e., with no transparency). As the user moves towards a virtual object and it intersects the far shell, its opacity begins to fade out with increasing transparency to reveal the background behind it. The transparency of the virtual object increases as the object gets closer to the near shell and the object becomes fully transparent when the near shell reaches it so that the background becomes fully visible.

16 Claims, 17 Drawing Sheets



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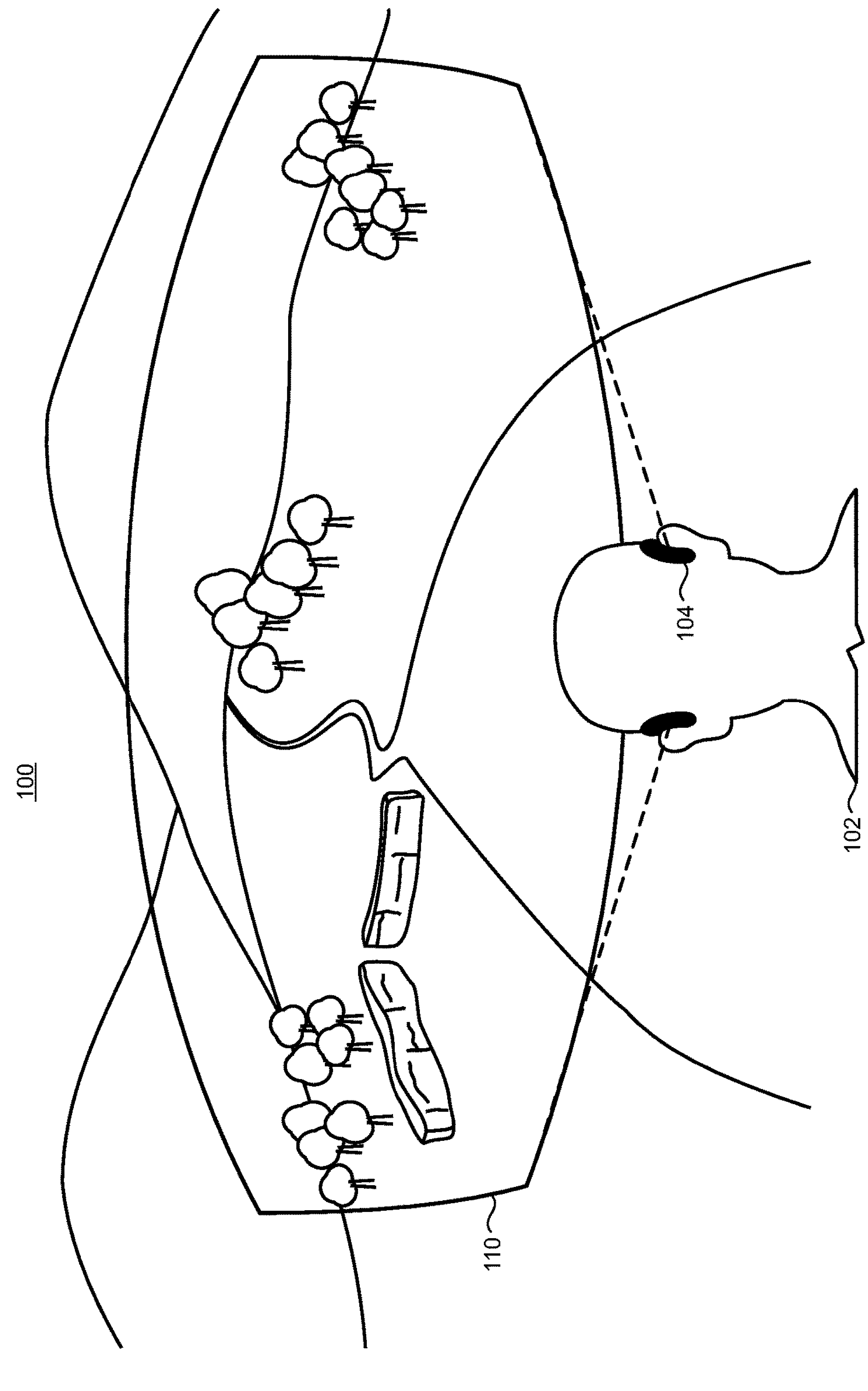


FIG 1

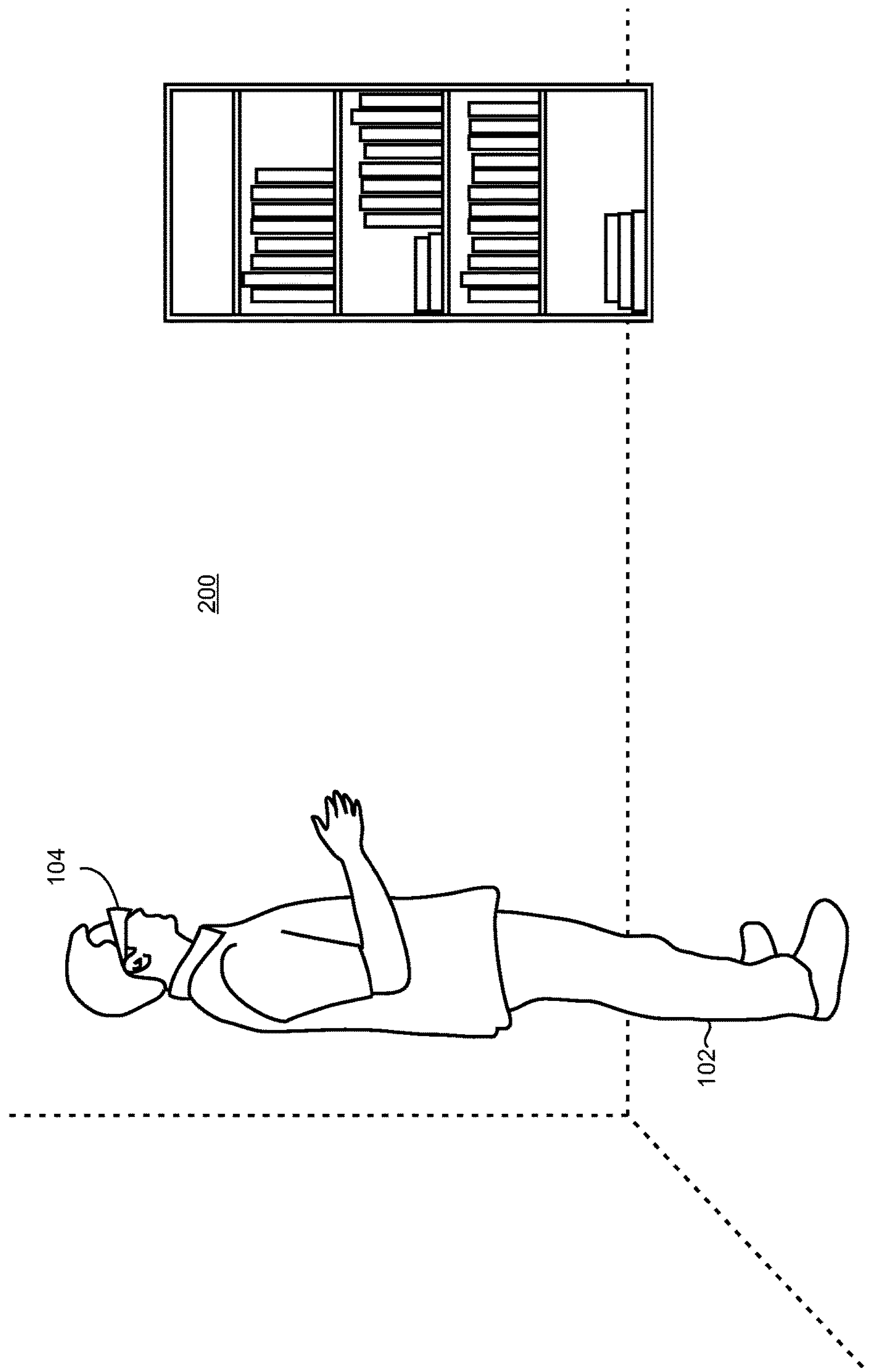


FIG 2

FIG 3

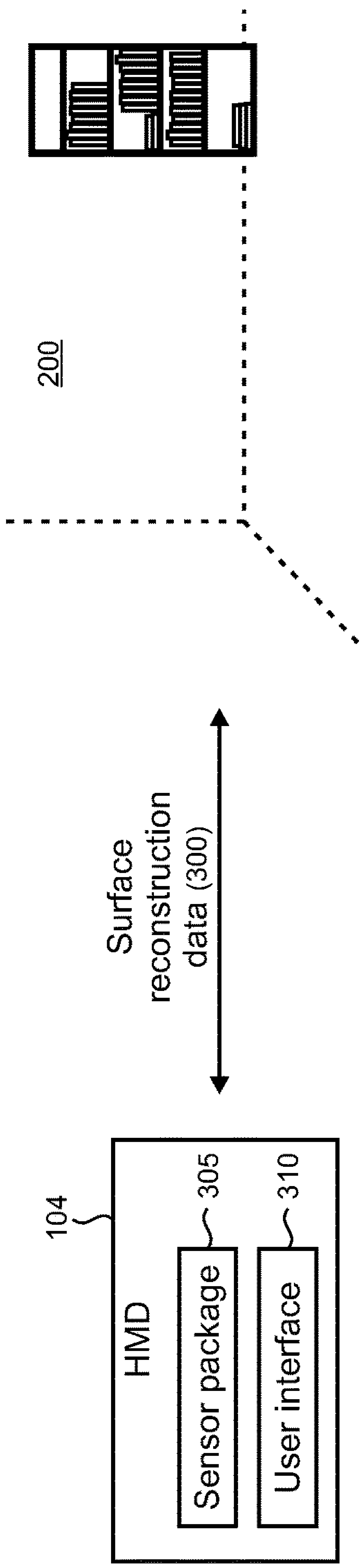
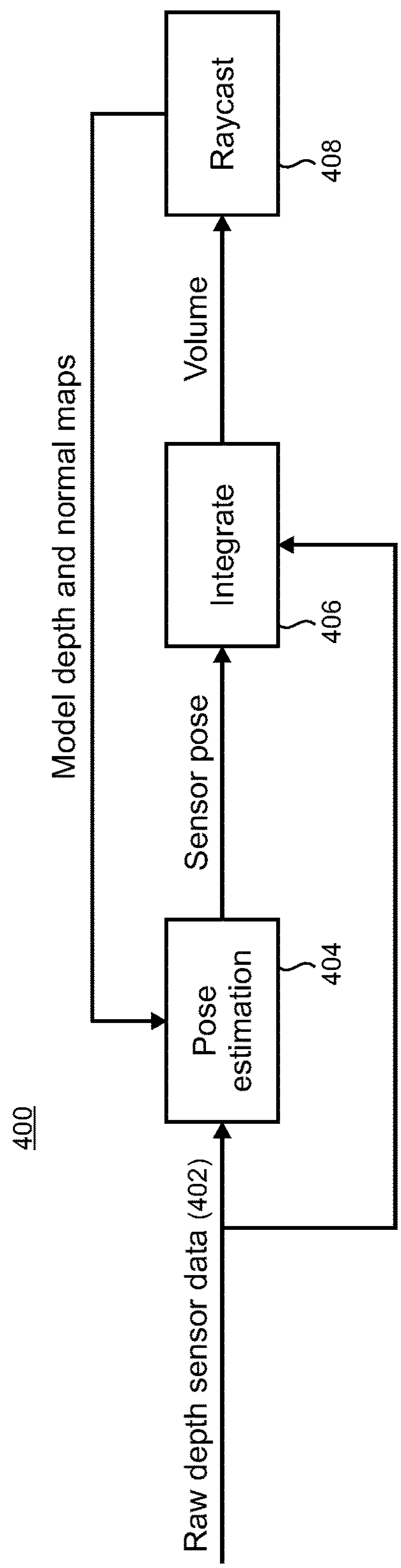

200
Surface reconstruction data (300)
104
HMD
Sensor package
305
User interface
310

FIG 4


400
Raw depth sensor data (402)
Pose estimation
404
Sensor pose
Integrate
406
Volume
Raycast
408
Model depth and normal maps

500

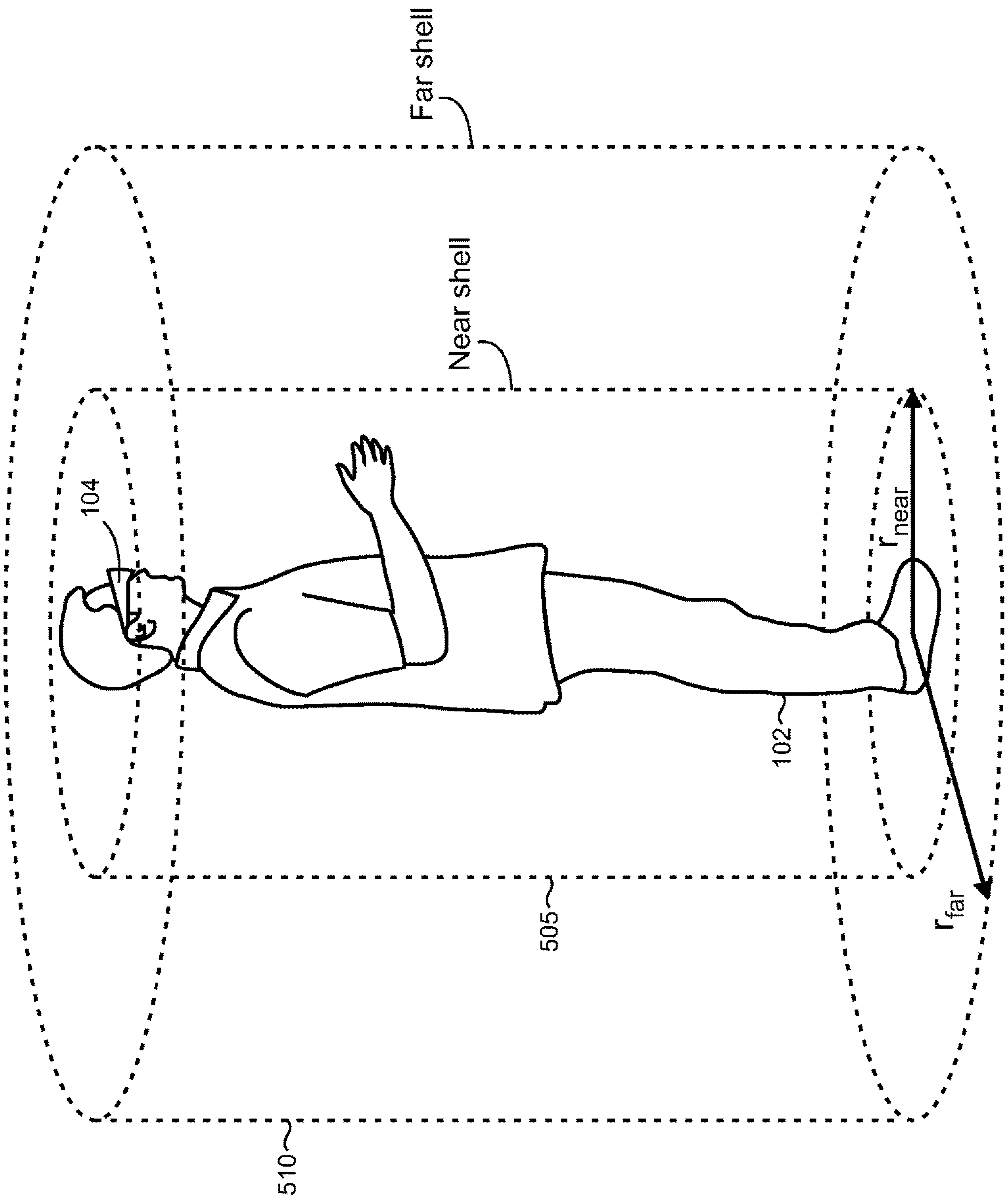


FIG 5

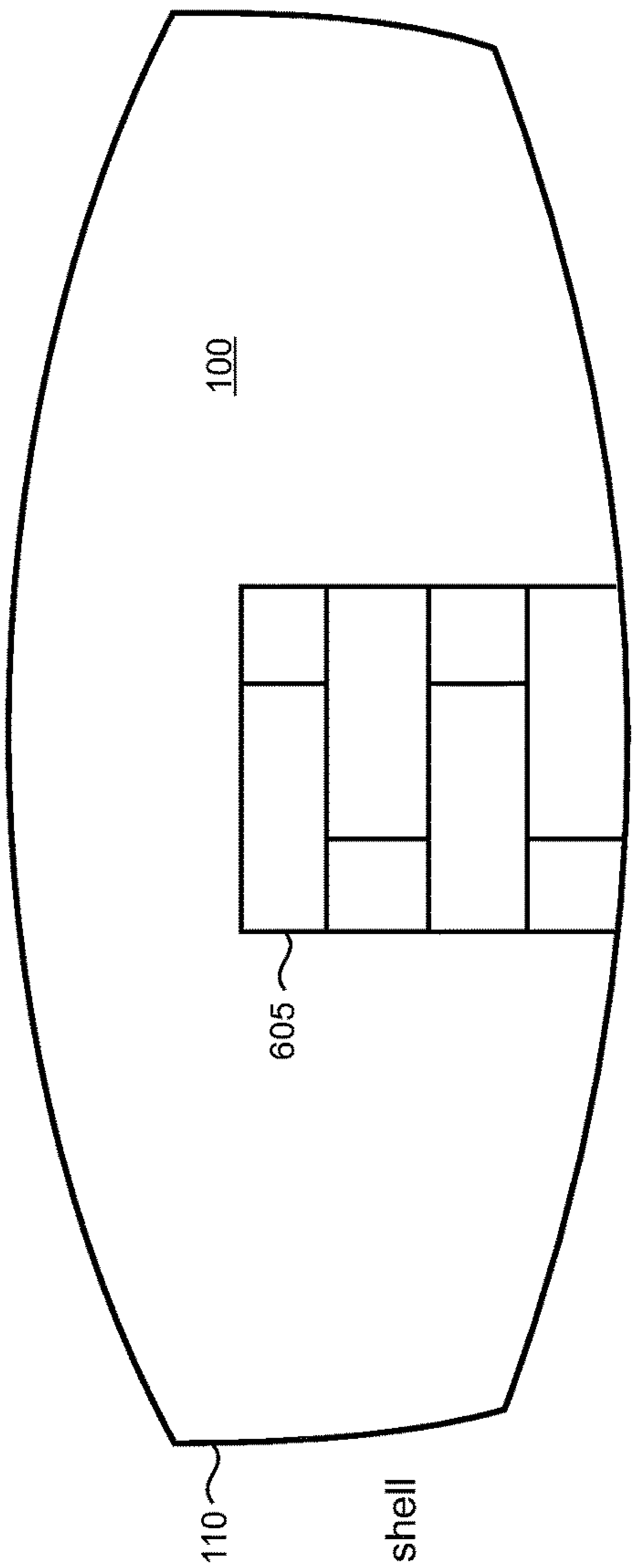


FIG 6

Beyond the far shell

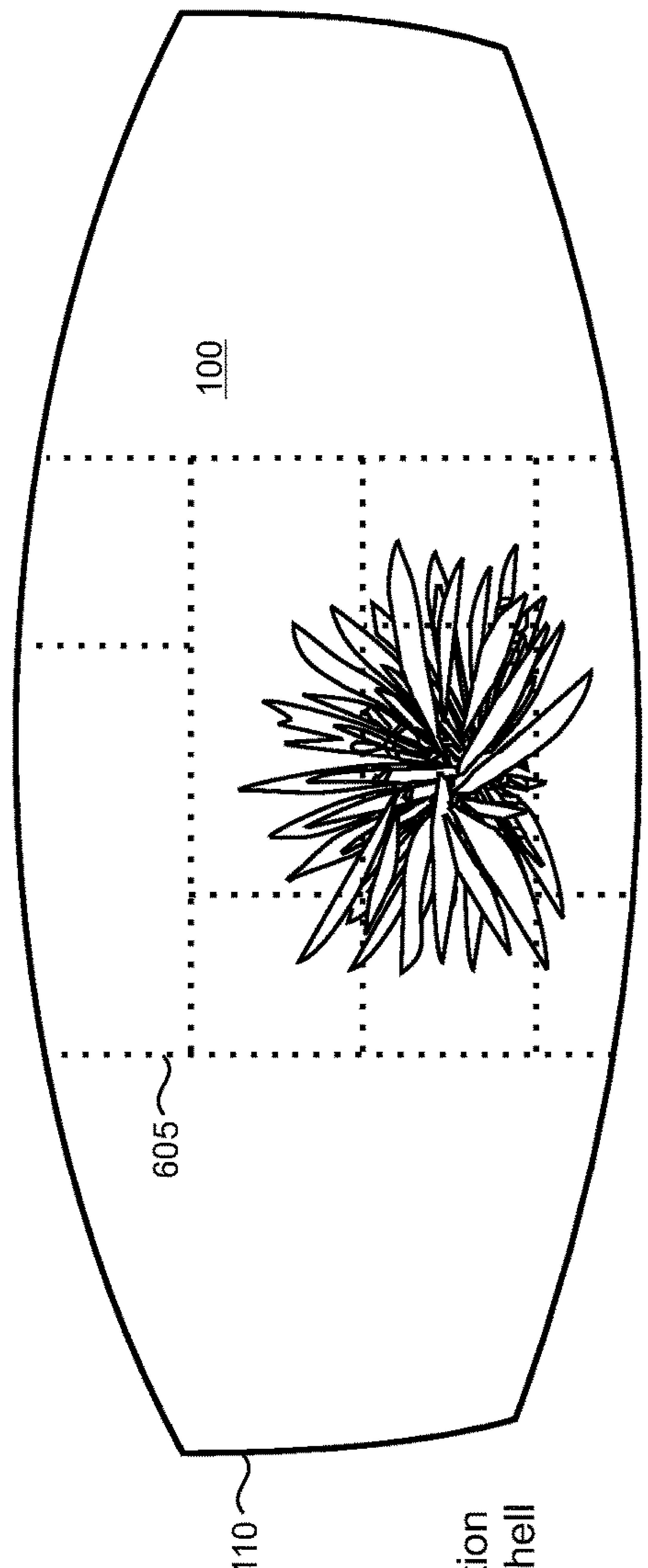


FIG 7

Upon intersection with the near shell

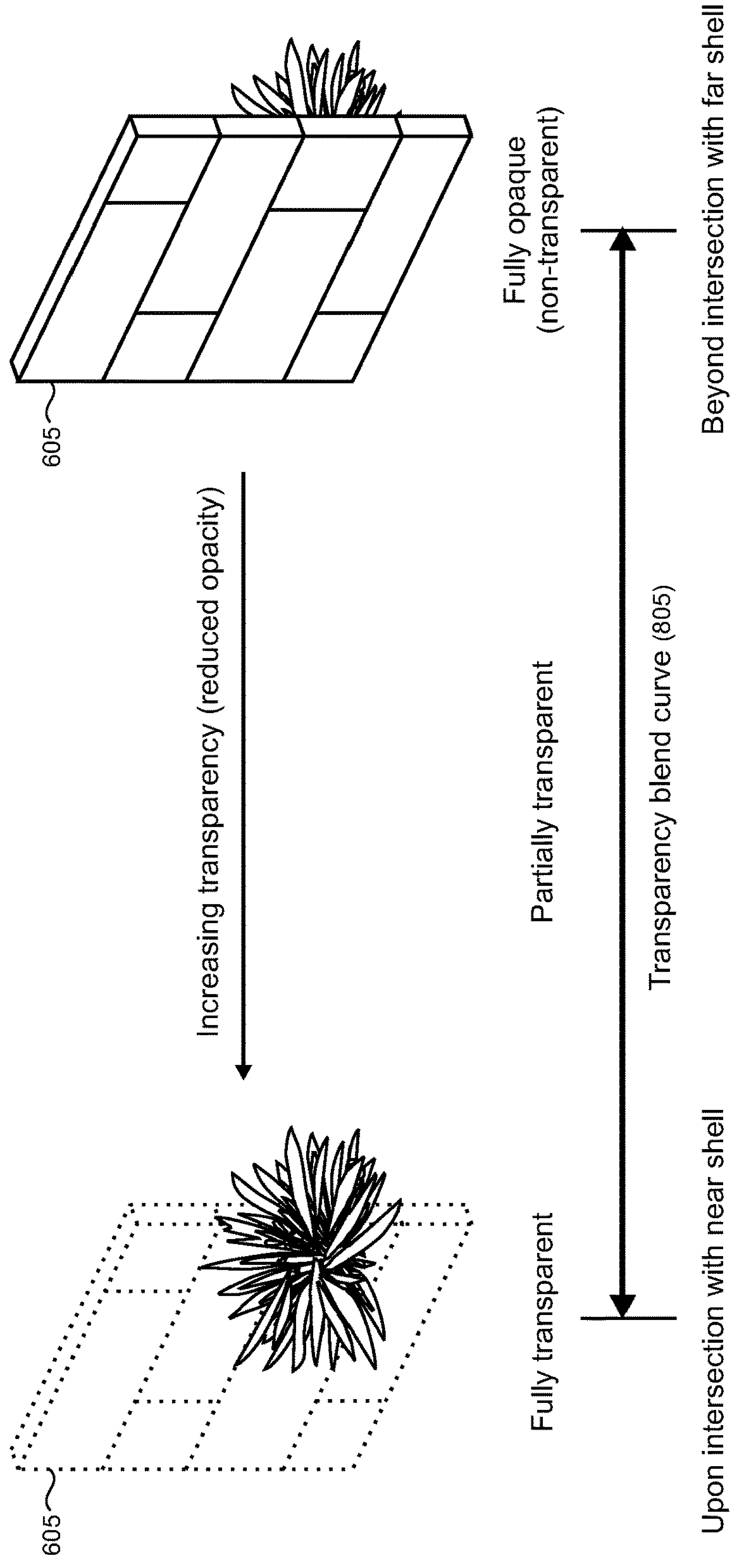

605
605
Increasing transparency (reduced opacity)
Fully transparent
Partially transparent
Fully opaque
(non-transparent)
Transparency blend curve (805)
Upon intersection with near shell
Beyond intersection with far shell

FIG 8

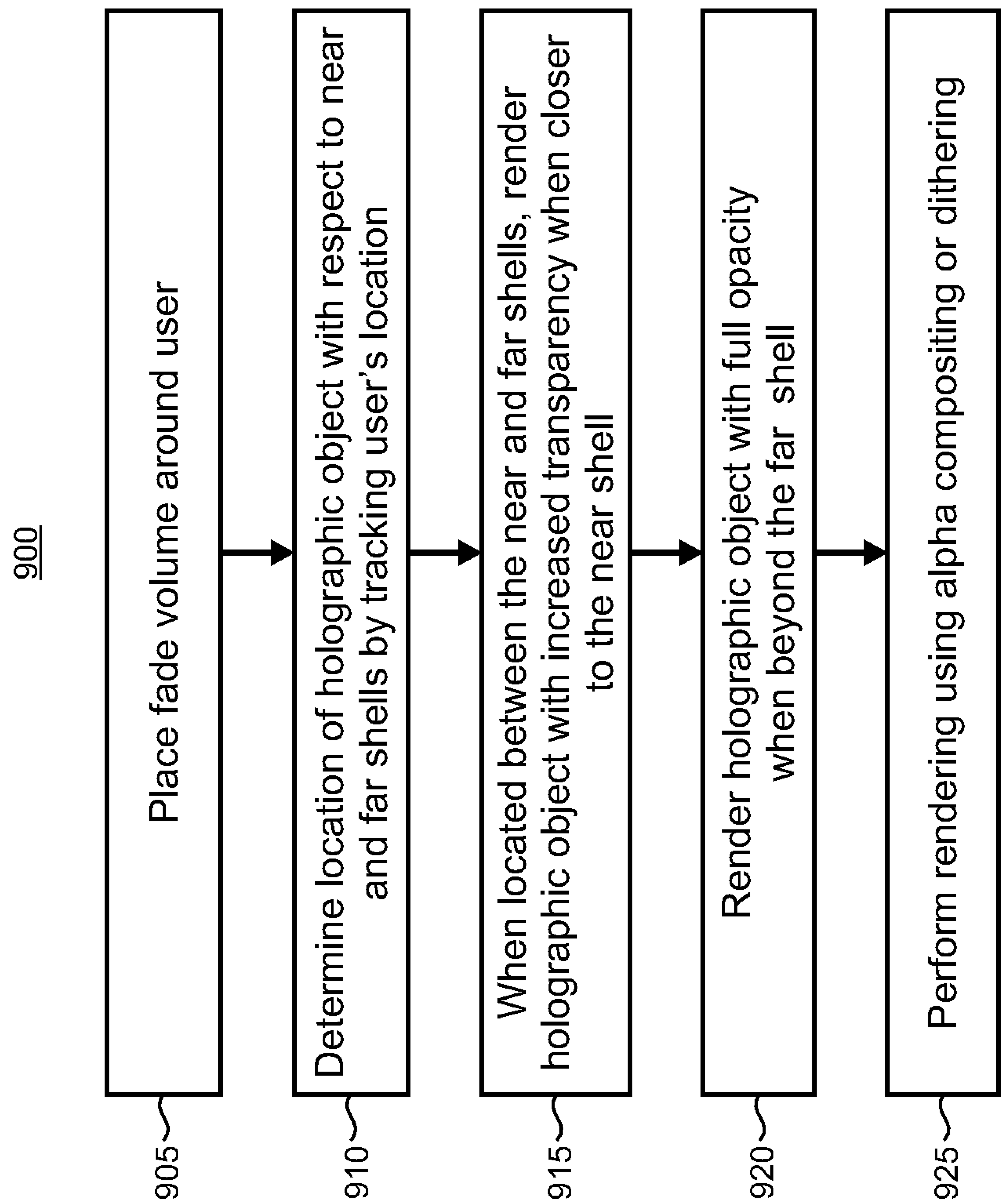

900
905
Place fade volume around user
910
Determine location of holographic object with respect to near and far shells by tracking user's location
915
When located between the near and far shells, render holographic object with increased transparency when closer to the near shell
920
Render holographic object with full opacity when beyond the far shell
925
Perform rendering using alpha compositing or dithering

FIG 9

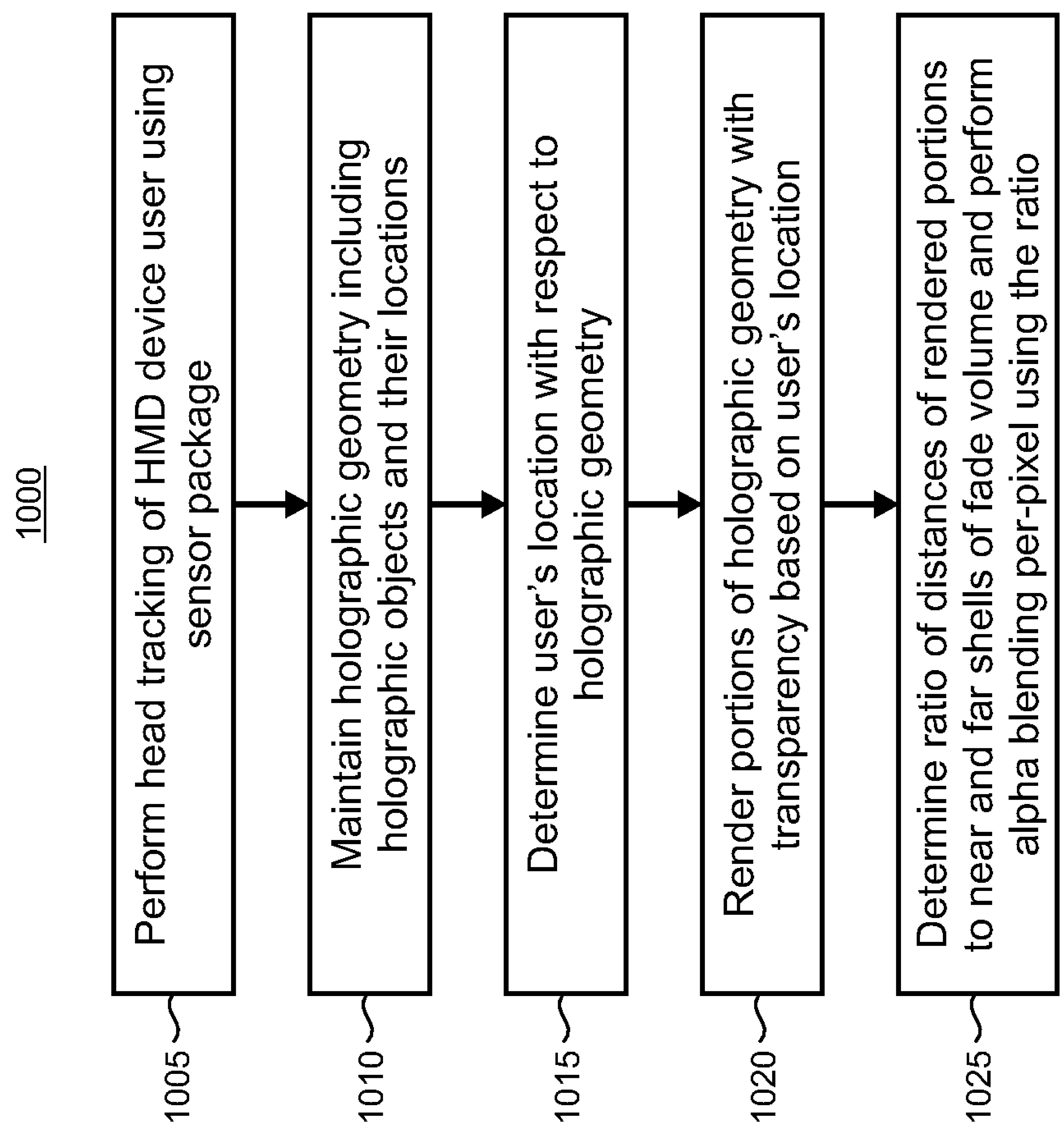
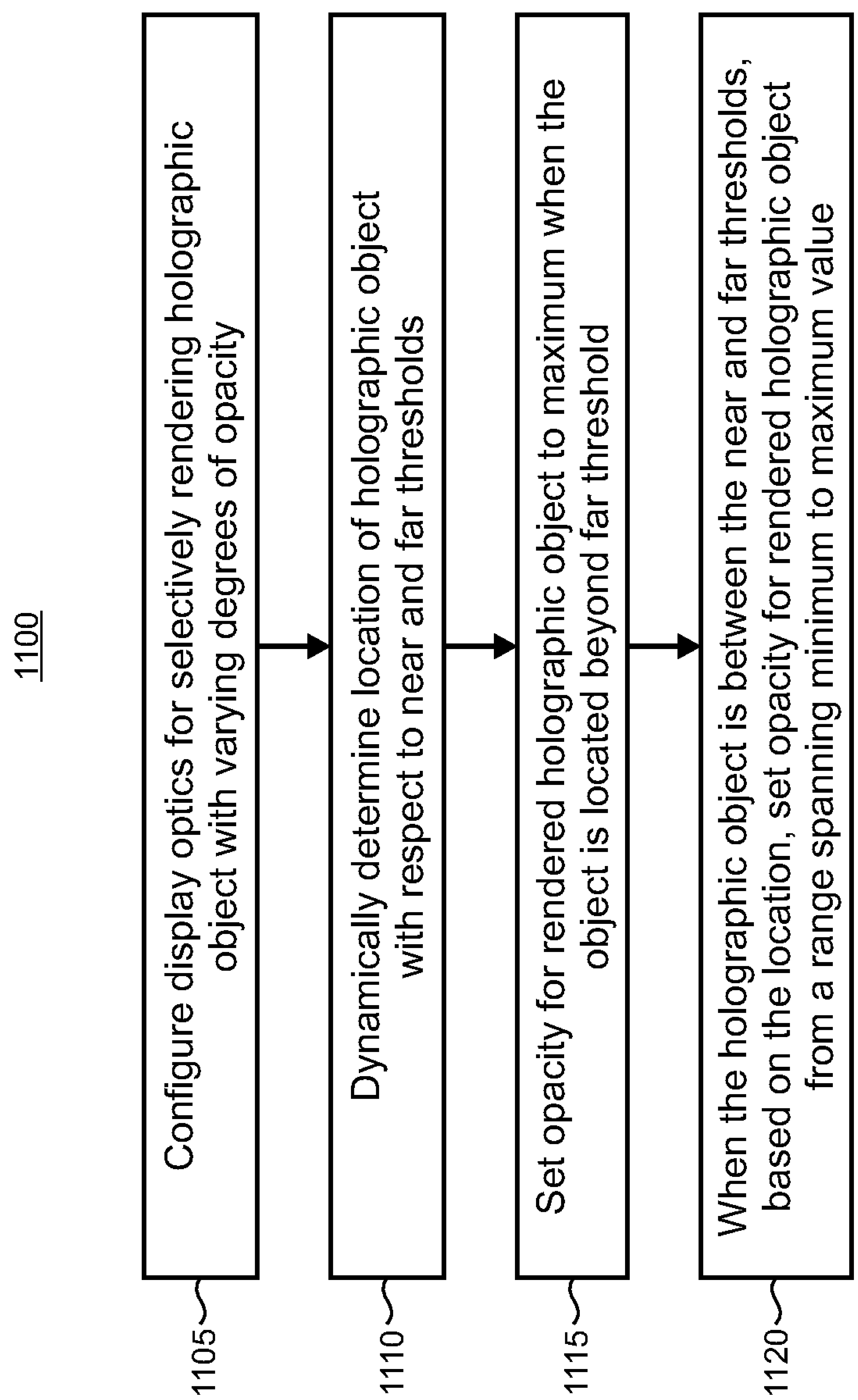

1000
Perform head tracking of HMD device user using sensor package
1005
Maintain holographic geometry including holographic objects and their locations
1010
Determine user's location with respect to holographic geometry
1015
Render portions of holographic geometry with transparency based on user's location
1020
Determine ratio of distances of rendered portions to near and far shells of fade volume and perform alpha blending per-pixel using the ratio
1025

FIG 10

FIG 11


1100
1105
Configure display optics for selectively rendering holographic object with varying degrees of opacity
1110
Dynamically determine location of holographic object with respect to near and far thresholds
1115
Set opacity for rendered holographic object to maximum when the object is located beyond far threshold
1120
When the holographic object is between the near and far thresholds, based on the location, set opacity for rendered holographic object from a range spanning minimum to maximum value

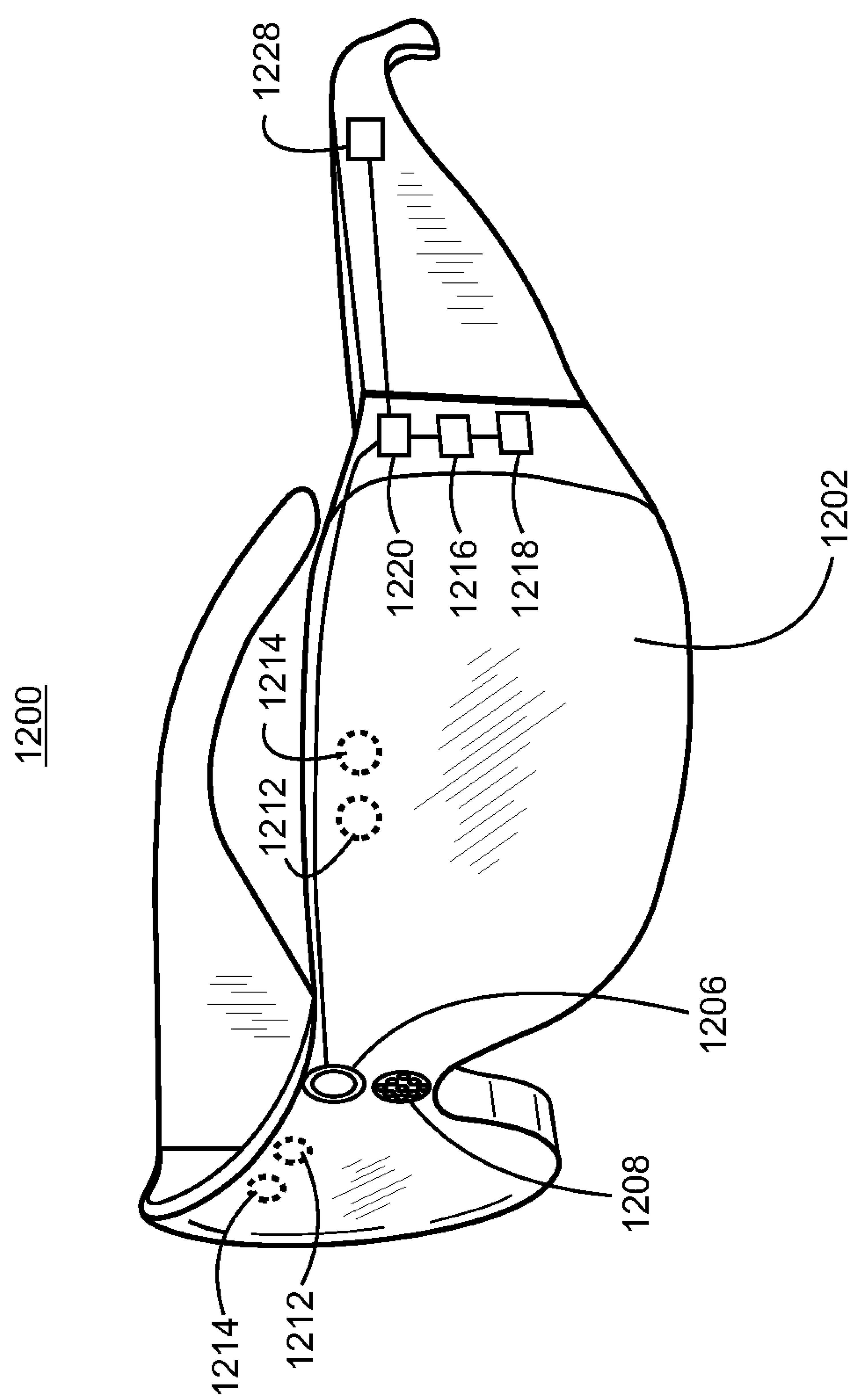


FIG 12

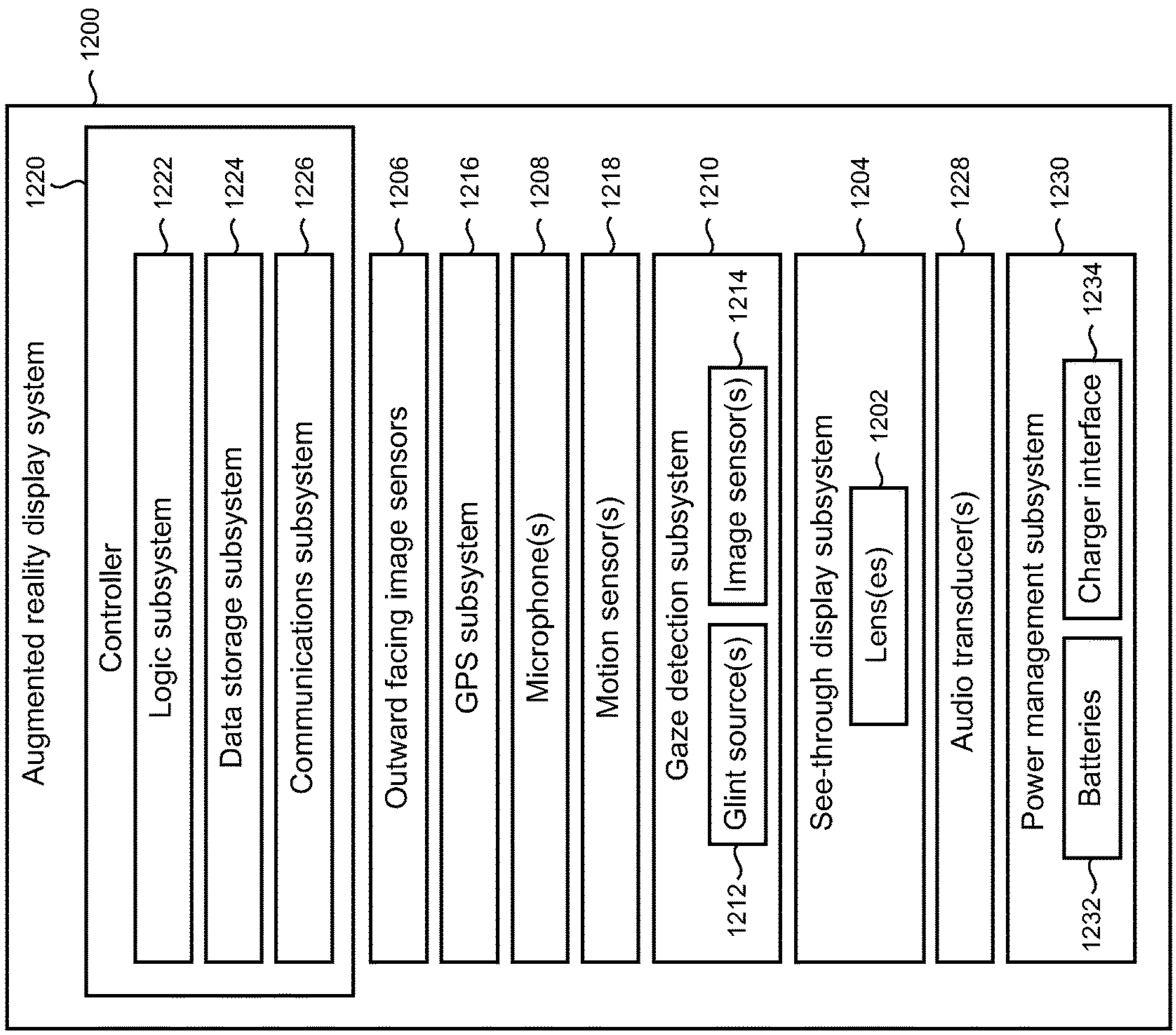

1200
Augmented reality display system
1220
Controller
1222
Logic subsystem
1224
Data storage subsystem
1226
Communications subsystem
1206
Outward facing image sensors
1216
GPS subsystem
1208
Microphone(s)
1218
Motion sensor(s)
1210
Gaze detection subsystem
1212
Glint source(s)
1214
Image sensor(s)
1204
See-through display subsystem
1202
Lens(es)
1228
Audio transducer(s)
1230
Power management subsystem
1232
Batteries
1234
Charger interface

FIG 13

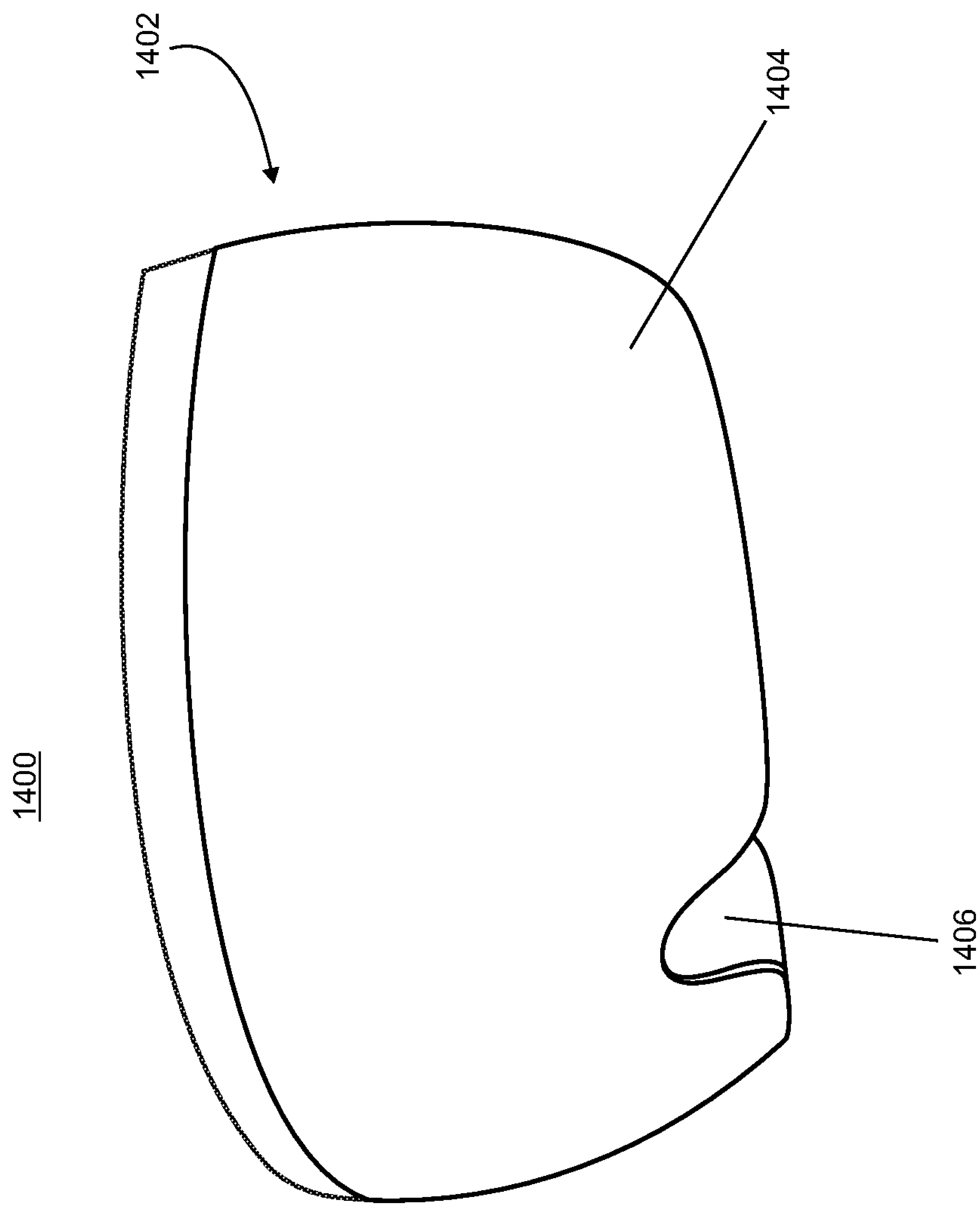


FIG 14

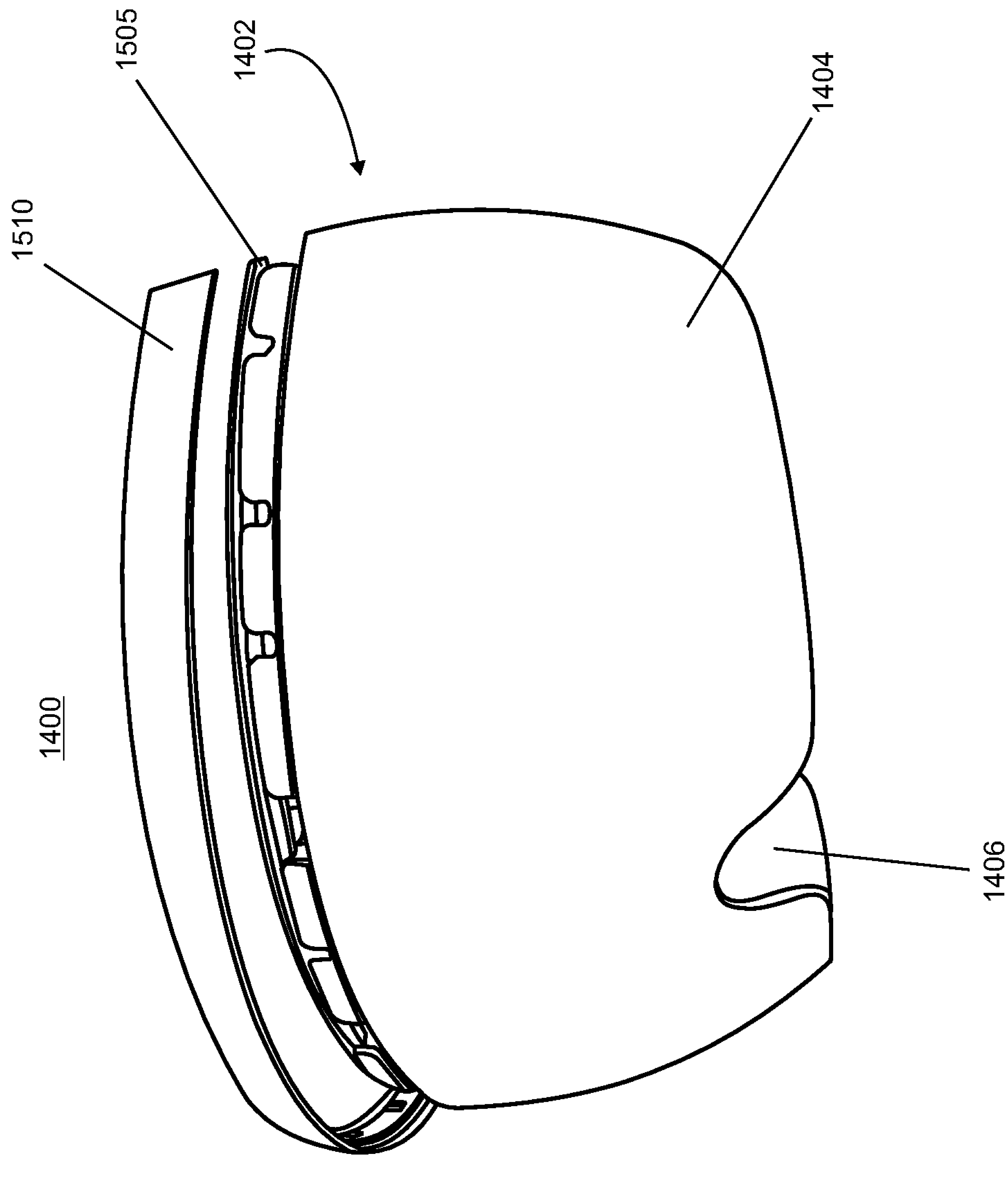


FIG 15

1400

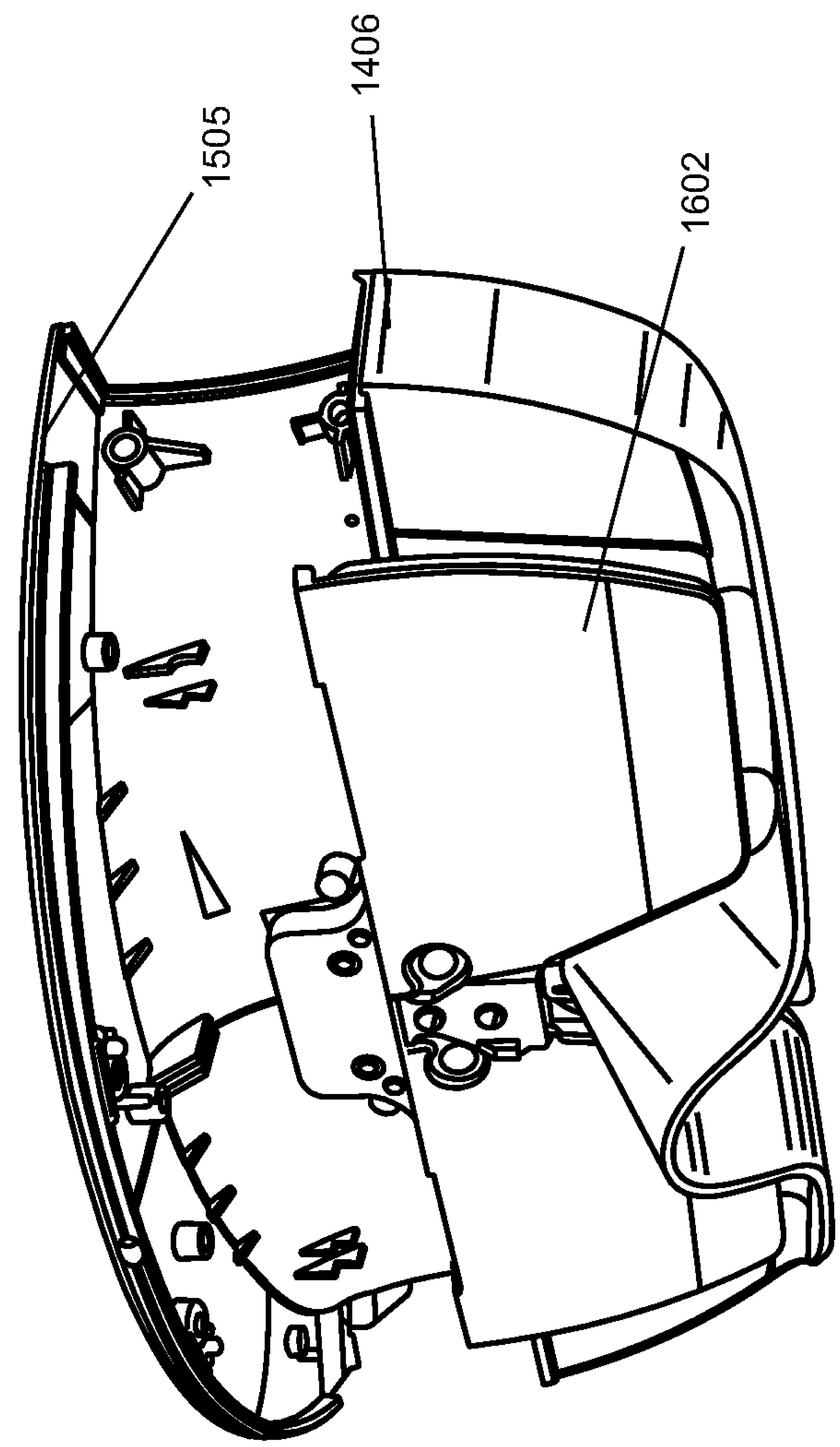


FIG 16

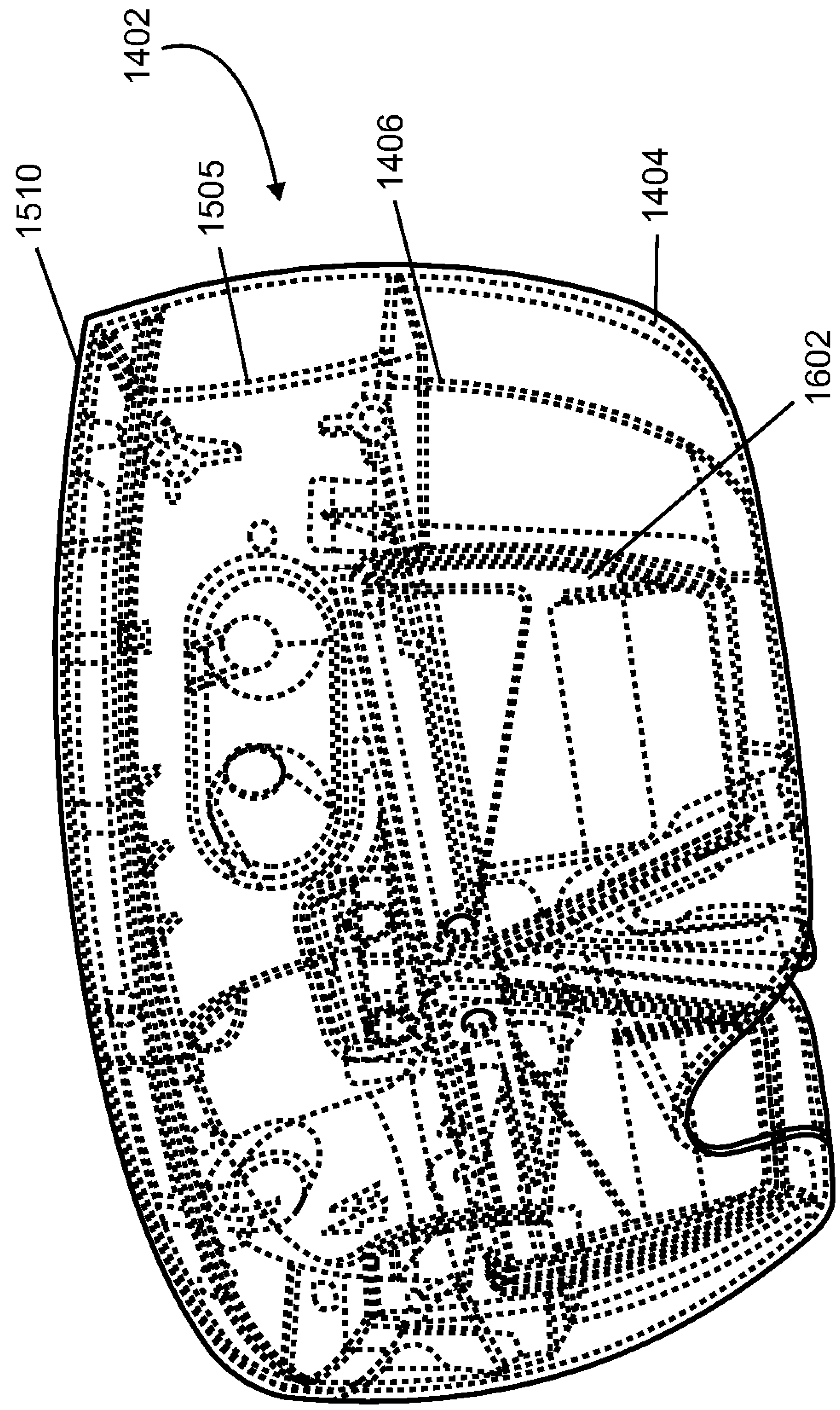


FIG 17

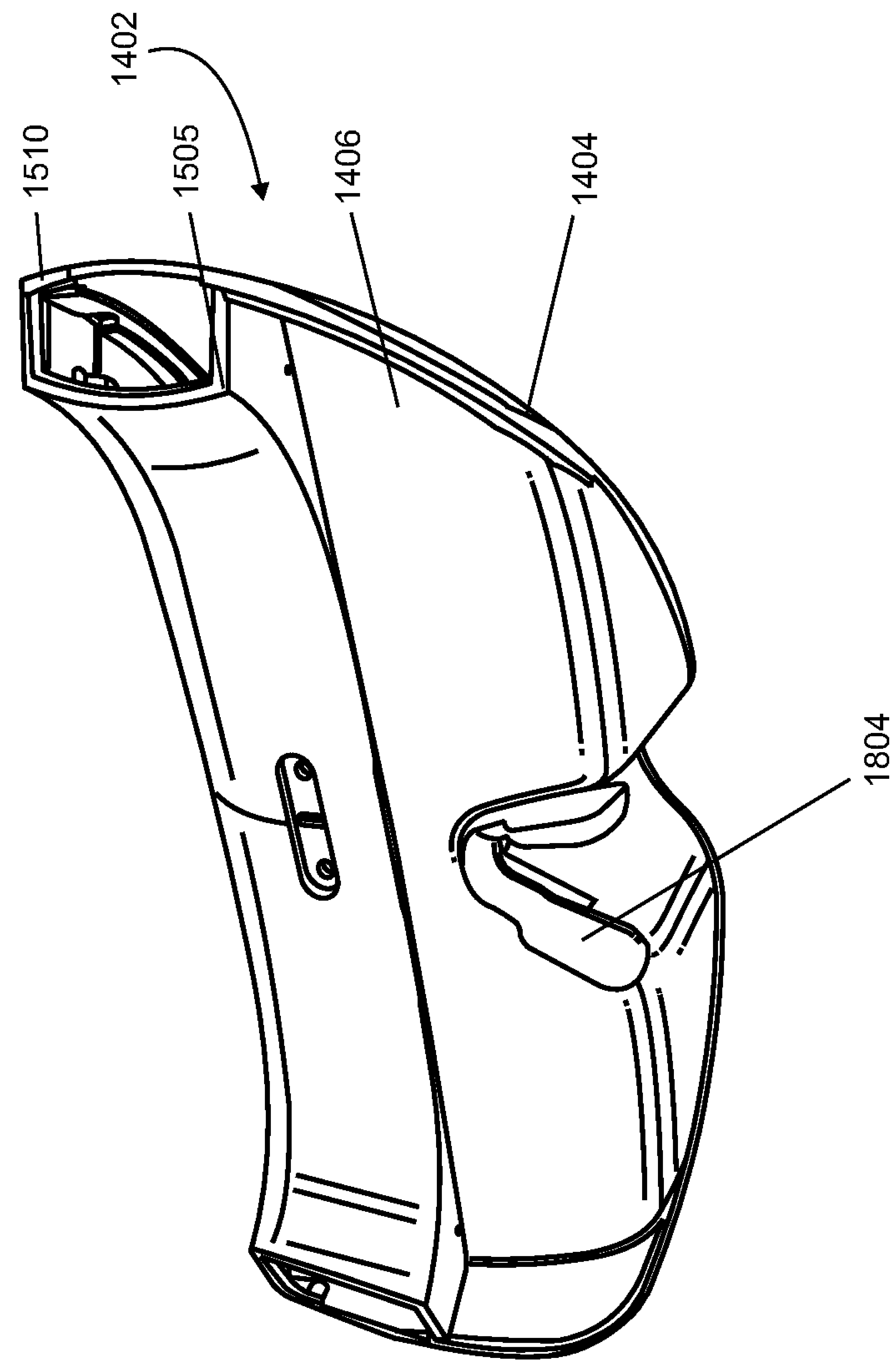


FIG 18

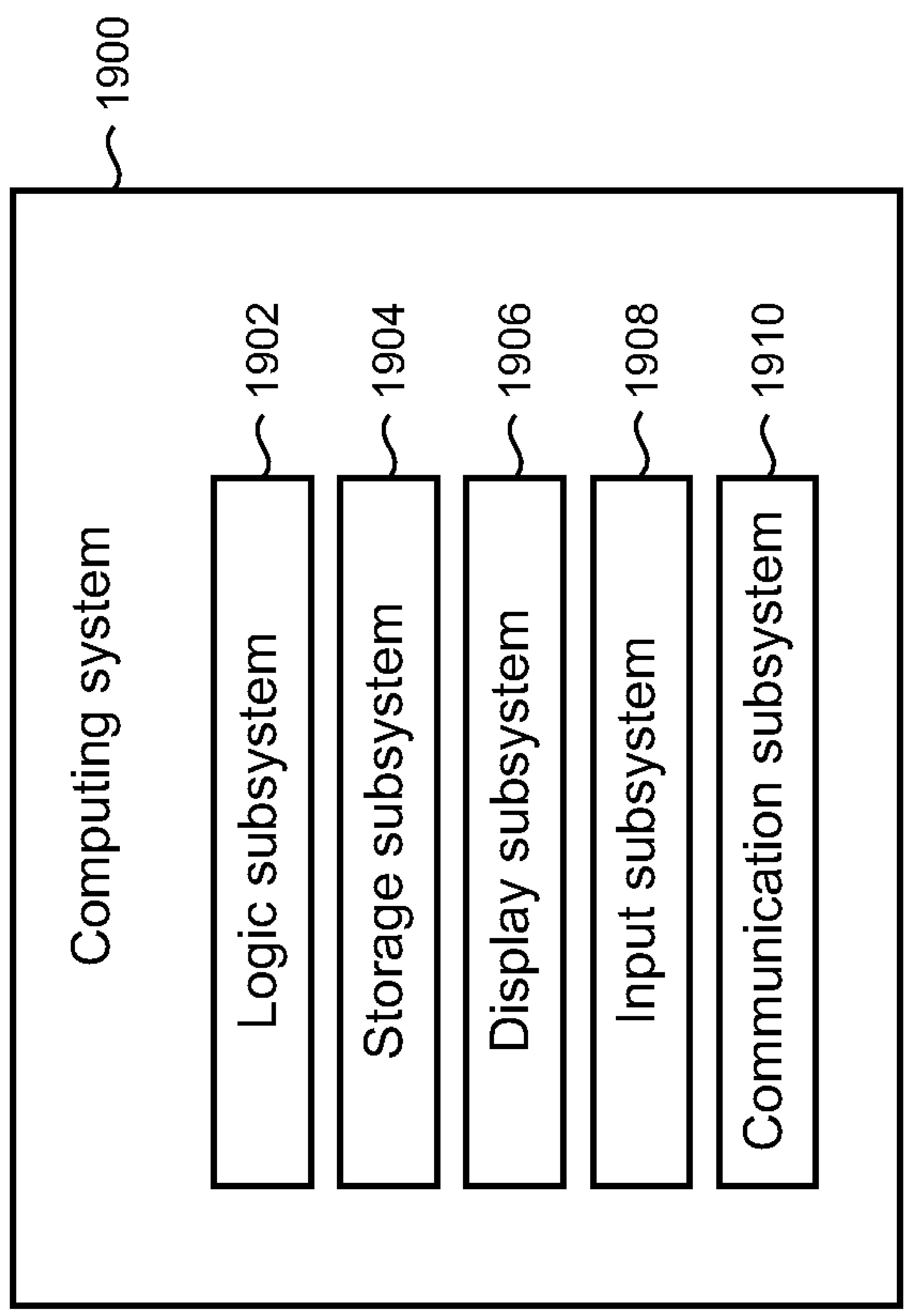

1900
Computing system
1902
Logic subsystem
1904
Storage subsystem
1906
Display subsystem
1908
Input subsystem
1910
Communication subsystem

FIG 19

SMART TRANSPARENCY FOR VIRTUAL OBJECTS

STATEMENT OF RELATED APPLICATIONS

This application claims benefit and priority to U.S. Provisional Application Ser. No. 62/029,351 filed Jul. 25, 2014, entitled "Head Mounted Display Experiences" which is incorporated herein by reference in its entirety.

BACKGROUND

Mixed reality and virtual reality computing devices, such as head mounted display (HMD) systems and handheld mobile devices (e.g. smart phones, tablet computers, etc.), may be configured to display information to a user about virtual and/or real objects in the field of view of the user and/or a field of view of a camera of the device. For example, an HMD device may be configured to display—using a see-through display system or an opaque display system with camera pass-through or other outward sensor—virtual environments with real world objects mixed in, real world environments with virtual objects mixed in, or pure virtual worlds. Similarly, a mobile device may display such information using a camera viewfinder window.

This Background is provided to introduce a brief context for the Summary and Detailed Description that follow. This Background is not intended to be an aid in determining the scope of the claimed subject matter nor be viewed as limiting the claimed subject matter to implementations that solve any or all of the disadvantages or problems presented above.

SUMMARY

An HMD device is configured with a sensor package that enables head tracking to determine the device user's proximity to holographic objects in a mixed reality or virtual reality environment. A fade volume including concentrically-arranged volumetric shells is placed around the user including a near shell that is closest to the user, and a far shell that is farthest from the user. When a holographic object is beyond the far shell, the HMD device renders the object with full opacity (i.e., with no transparency). As the user moves towards a holographic object and it intersects the far shell, its opacity begins to fade out with increasing transparency to reveal the background behind it. The transparency of the holographic object increases as the object gets closer to the near shell and the object becomes fully transparent when the near shell reaches it so that the background becomes fully visible.

In various illustrative examples, alpha compositing is utilized and an alpha value is determined on a per-pixel basis depending on respective proximity to the near and far shells. A transparency blend curve may be utilized to smoothly blend the per-pixel alpha value over the distance between the near and far shells. Fading opacity and increasing transparency as the user approaches holographic objects can help to reduce visual discomfort and prevent occlusion of the background that the objects would otherwise hide. In another example, transparency may be implemented using a dithering technique.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure. It may be appreciated that the above-described subject matter may be implemented as a computer-controlled apparatus, a computer process, a computing system, or as an article of manufacture such as one or more computer-readable storage media. These and various other features may be apparent from a reading of the following Detailed Description and a review of the associated drawings.

DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an illustrative virtual reality environment, a portion of which is rendered within the view of a user of an HMD device;

FIG. **2** shows an illustrative real world environment in which a user of an HMD device is located;

FIG. **3** depicts surface reconstruction data associated with real world objects being captured by an HMD device;

FIG. **4** shows a block diagram of an illustrative surface reconstruction pipeline;

FIG. **5** shows an HMD device user being represented by an illustrative fade volume that is sized according the user's height and uses concentric shells;

FIG. **6** shows an illustrative virtual object that is non-transparently rendered in the field of view of an HMD device when the object is located at, or beyond, the far shell of the fade volume;

FIG. **7** shows an illustrative virtual object that is transparently rendered in the field of view of an HMD device when the object is located at, or within, the near shell of the fade volume;

FIG. **8** shows an illustrative transparency blend curve that is applied to virtual objects as they are located at various points between the near and far shells of the fade volume;

FIGS. **9**, **10**, and **11** are flowcharts of illustrative methods that may be performed using an HMD device;

FIG. **12** is a pictorial view of an illustrative example of a mixed reality HMD device;

FIG. **13** shows a functional block diagram of an illustrative example of a mixed reality HMD device;

FIGS. **14** and **15** are pictorial front views of a sealed visor that may be used as a component of a mixed reality HMD device;

FIG. **16** shows a partially disassembled view of the sealed visor;

FIG. **17** shows a phantom line front view of the sealed visor;

FIG. **18** shows a pictorial back view of the sealed visor; and

FIG. **19** shows an exemplary computing system.

Like reference numerals indicate like elements in the drawings. Elements are not drawn to scale unless otherwise indicated.

DETAILED DESCRIPTION

When experiencing a mixed or virtual reality environment while using an HMD device, users can move into holographic virtual objects as they move around in a corresponding real world space. Such movement can present technical challenges for the HMD device in accurately rendering objects as the draw distance decreases (and approaches zero) and may cause user discomfort due to mismatch in clip planes between each eye. In addition, as a holographic object fills the field of view of the HMD device as the user gets closer, the object can occlude vision of the floor or other objects. The present smart transparency provides for holographic object opacity that fades out (and transparency increases) as the HMD device user approaches to reduce both visual discomfort and occlusion of other objects such as the background object and floor.

In an illustrative example, as shown in FIG. **1**, a user **102** can employ an HMD device **104** to experience a virtual reality environment **100** that is rendered visually and may include audio and/or tactile/haptic sensations in some implementations. In this particular non-limiting example, an application executing on the HMD device **104** supports a virtual reality environment **100** that includes an outdoor landscape with plants and trees, rolling hills, fences, roads, etc., with which the user can interact and see. As the user changes the position or orientation of his head and/or moves within a corresponding real world physical environment **200** shown in FIG. **2**, his view of the virtual reality environment can change. The field of view (represented by the dashed area **110** in FIG. **1**) can be sized and shaped and other characteristics of the device can be controlled to make the HMD device experience visually immersive to provide the user with a strong sense of presence in the virtual world. While a virtual reality environment is shown and described herein, the present smart transparency can also be applied to mixed reality environments and scenarios.

The HMD device **104** is configured to determine the position of the user in the virtual reality environment and his relationship to holographic objects by tracking the user's position, including his head, in the physical environment **200**. As shown in FIG. **3**, the device is configured to obtain surface reconstruction data **300** by using a sensor package **305** that may include an integrated depth sensor. In alternative implementations, depth data can be derived using suitable stereoscopic image analysis techniques. Surface reconstruction may be utilized, for example, for head tracking to determine the 3D (three-dimensional) position and orientation of the user's head within the physical real world environment **200** including head pose so that a view position of the virtual world can be determined.

The sensor package can also support gaze tracking to ascertain a direction of the user's gaze which may be used along with the head position and orientation data in some implementations. The HMD device **104** may further be configured to expose a user interface (UI) **310** that can display system messages, prompts, and the like as well as expose controls that the user may manipulate. The controls can be virtual or physical in some cases. The UI **310** may also be configured to operate with sensed gestures and voice using, for example, voice commands or natural language.

FIG. **4** shows an illustrative surface reconstruction data pipeline **400** for obtaining surface reconstruction data for objects in the real world space. It is emphasized that the disclosed technique is illustrative and that other techniques and methodologies may be utilized depending on the requirements of a particular implementation. Raw depth sensor data **402** is input into a 3D (three-dimensional) pose estimate of the sensor (block **404**). Sensor pose tracking can be achieved, for example, using ICP (iterative closest point) alignment between the predicted surface and current sensor measurement. Each depth measurement of the sensor can be integrated (block **406**) into a volumetric representation using, for example, surfaces encoded as a signed distance field (SDF). Using a loop, the SDF is raycast (block **408**) into the estimated frame to provide a dense surface prediction to which the depth map is aligned.

To determine when a user is close to a holographic object, the HMD device **104** places a fade volume **500** around the user **102**, as shown in FIG. **5**, which includes a near shell **505** and a far shell **510**. In this particular illustrative example and not by way of limitation, the shells **505** and **510** are cylindrical and substantially concentrically aligned and the radius of the near shell, r_{near}, is approximately a half meter and the radius of the far shell, r_{far} is approximately one meter. It is emphasized that the concentricity and the radius dimensions are intended to be illustrative and that other arrangements and dimensions may be utilized to suit a particular application of smart transparency.

The fade volume **500** can be configured using a variety of geometries such as the cylinder as depicted in FIG. **5**, capsules, or spheres, or other shapes, and it is noted that the fade volume may be implemented using non-radial volumes in some cases. The fade volume is generally sized according to the user's head location within the physical environment and may change accordingly as the user's head height above the ground changes, for example, if the user ducks or keeps low while moving. The user's head height can be determined using any suitable technique including, for example, head tracking using the HMD's sensor package as described above, image analyses for estimating the user's head height from the floor, or with external/remote methods.

As the user moves in the virtual reality environment **100** (FIG. **1**) the distance from the fade volume **500** to a given holographic object is continuously determined. In an illustrative example, an alpha value is set by the HMD device in an alpha compositing process to render the object with full opacity, full transparency, or some degree of transparency depending on the object's proximity to the near and far shells. For example, as shown in FIG. **6**, a wall **605** in the virtual world **100** is rendered on the HMD's field of view **110** with full opacity when it is located beyond the far shell **510** (FIG. **5**) of the fade volume **500**. As the user moves towards the wall, when the wall reaches the near shell **505** of the fade volume, the HMD device will render the wall with full transparency (full transparency is indicated with dotted lines in the drawings) so that whatever is behind the wall (e.g., other objects and/or the ground) is visible, as illustratively depicted in FIG. **7**.

As shown in FIG. **8**, as the user moves and the wall **605** passes between the far and near shells in the fade volume, the wall is rendered with increasing transparency as it gets closer to the near shell. That is, the wall is fully opaque beyond the far shell. As the user moves towards the wall, the wall becomes more transparent as the user draws closer (so the user can begin to see what is behind the wall), until the wall becomes fully transparent when the user becomes so close that the wall intersects the near shell (so the user has complete visibility of the virtual world that is behind the wall).

The alpha compositing of the transparency may be performed on a per-pixel basis and the alpha value can be varied using a transparency blend curve that is imposed over the spatial distance between the near and far shells, as represented by reference numeral **805** in FIG. **8**. For example, the transparency blend may be determined based on a value between 0 and 1 that describes a ratio of the holographic object's respective distances from the near and far shells. Accordingly, the transparency blend curve **805** can be selected from any function that blends from 0 and 1 over the distance range between the near and far shells. For example, the alpha value can be linearly interpolated over the distance range but other transparency blend curves using non-linear functions may also be utilized to meets the requirements of a particular implementation of smart transparency.

In some implementations of smart transparency, adjustments may be made to properties of a holographic object other than alpha value. For example, the RGB (red, green, blue) channel values of a holographic object can be adjusted to fade the object to black. When implemented in an HMD device that uses an additive display, holographic content rendered in black is transparent so that real world objects are visible. Such real world visibility can be utilized in mixed reality environments that support a combination of holographic and real world content. For example, as the user moves closer to a holographic object, it is rendered to black to become transparent and reveal portions of the real world that are behind it.

Other techniques to implement smart transparency may also be utilized for a given application. For example, in addition to alpha compositing, dithering techniques such as ordered dithering can be utilized in which a threshold matrix provides multiple dithering patterns for the holographic object to produce varying degrees of transparency. A pixel in the holographic object is discarded (and become invisible) when it is below a given threshold. The threshold matrix can be implemented as a dither matrix (also commonly referred to as an index matrix or Bayer matrix) which typically provides a regular dithering pattern, however, random permutations of the threshold values can also be utilized in some cases.

FIGS. **9**, **10**, and **11** are flowcharts of illustrative methods that may be performed using the HMD device **104**. Unless specifically stated, the methods or steps shown in the flowcharts and described in the accompanying text are not constrained to a particular order or sequence. In addition, some of the methods or steps thereof can occur or be performed concurrently and not all the methods or steps have to be performed in a given implementation depending on the requirements of such implementation and some methods or steps may be optionally utilized.

Method **900** shown in FIG. **9** may be performed by an HMD device supporting rendering of a mixed reality or virtual reality environment that is operable by a user in a physical environment. In step **905**, a fade volume is placed around the device user. The fade volume has a near shell that is proximate (i.e., near) to the user and a far shell that is distal (i.e., away) from the user. The fade volume can be sized according to the user's current head height which can be determined using the onboard sensor package in the HMD device and may be configured using cylinders or spheres, for example. In step **910**, a location of a holographic object is determined by tracking the user's location within the mixed reality or virtual reality environment. Such tracking may be performed, for example, using head tracking that may be enabled using the sensor package that supports depth sensing and other capabilities.

In step **915**, when the holographic object is located between the near and far shells, it is rendered with increased transparency as the location is closer to the near shell. When the location intersects the near shell, the holographic object may be rendered with full transparency to reveal the background of the environment. In step **920**, the holographic object is rendered by the HMD device when it is located beyond the far shell. In step **925**, the rendering of the holographic object may be performed using alpha compositing and on per-pixel basis in some implementations. An alpha value can be interpolated based on a transparency curve that is established over the spatial distance between the near and far shells. The interpolation may be linear in some cases. Rendering may also be alternatively implemented using a dithering technique such as ordered dithering.

Method **1000** shown in FIG. **10** may be performed by a HMD device having one or more processors, a display for rendering a mixed reality or virtual reality environment using a variable field of view, a sensor package, and one or more memory devices that store computer-readable instructions such as software code that can be utilized to implement the method. In step **1005**, head tracking of the HMD device user is performed using the onboard sensor package. A holographic geometry is maintained in step **1010** that includes one or more holographic objects with known locations in the environment. In step **1015**, in response to the head tracking, the user's location with respect to the holographic geometry is determined Portions of the holographic geometry are rendered with some degree of transparency based on the user's location so that transparency is increased as the distance between the location and the rendered portions decrease in step **1020**. A ratio of distances of the rendered portions with respective near and fall shells of a fade volume that is placed around the user in step **1025** and alpha blending is performed using the ratio on a per-pixel basis.

Method **1100** in FIG. **11** may be performed by instructions stored on an HMD device operating in a real world environment. In step **1105**, display optics in the HMD device are configured for selectively rendering a holographic object with varying degrees of opacity. In step **1110**, a location of a holographic object is dynamically determined with respect to each of near and far thresholds using sensors that are incorporated into the device. In step **1115**, opacity for a rendered holographic object is set to a maximum value when the object is located beyond the far threshold. In step **1120**, when the holographic object is located between the near and far thresholds, based the location, the opacity for the rendered holographic object is set from a range that spans a minimum and the maximum value.

Turning now to various illustrative implementation details, a mixed and/or virtual reality display device according to the present arrangement may take any suitable form, including but not limited to near-eye devices such as the HMD device **104** and/or other portable/mobile devices. A see-through display may be used in some implementations while an opaque (i.e., non-see-through) display using a camera-based pass-through or outward facing sensor, for example, may be used in other implementations. FIG. **12** shows one particular illustrative example of a see-through, mixed reality display system **1200**, and FIG. **13** shows a functional block diagram of the system **1200**. Display system **1200** comprises one or more lenses **1202** that form a part of a see-through display subsystem **1204**, such that images may be displayed using lenses **1202** (e.g. using projection onto lenses **1202**, one or more waveguide systems incorporated into the lenses **1202**, and/or in any other suitable manner). Display system **1200** further comprises one or more outward-facing image sensors **1206** configured to acquire images of a background scene and/or physical environment being viewed by a user, and may include one or more microphones **1208** configured to detect sounds, such as voice commands from a user. Outward-facing image sensors **1206** may include one or more depth sensors and/or one or more two-dimensional image sensors. In alternative arrangements, as noted above, a mixed reality display system, instead of incorporating a see-through display subsystem, may display mixed reality images through a viewfinder mode for an outward-facing image sensor.

The display system **1200** may further include a gaze detection subsystem **1210** configured for detecting a direction of gaze of each eye of a user or a direction or location of focus, as described above. Gaze detection subsystem **1210** may be configured to determine gaze directions of each of a user's eyes in any suitable manner. For example, in the illustrative example shown, a gaze detection subsystem **1210** includes one or more glint sources **1212**, such as infrared light sources, that are configured to cause a glint of light to reflect from each eyeball of a user, and one or more image sensors **1214**, such as inward-facing sensors, that are configured to capture an image of each eyeball of the user. Changes in the glints from the user's eyeballs and/or a location of a user's pupil, as determined from image data gathered using the image sensor(s) **1214**, may be used to determine a direction of gaze.

In addition, a location at which gaze lines projected from the user's eyes intersect the external display may be used to determine an object at which the user is gazing (e.g. a displayed virtual object and/or real background object). Gaze detection subsystem **1210** may have any suitable number and arrangement of light sources and image sensors. In some implementations, the gaze detection subsystem **1210** may be omitted.

The display system **1200** may also include additional sensors. For example, display system **1200** may comprise a global positioning system (GPS) subsystem **1216** to allow a location of the display system **1200** to be determined. This may help to identify real world objects, such as buildings, etc. that may be located in the user's adjoining physical environment.

The display system **1200** may further include one or more motion sensors **1218** (e.g., inertial, multi-axis gyroscopic, or acceleration sensors) to detect movement and position/orientation/pose of a user's head when the user is wearing the system as part of an augmented reality HMD device. Motion data may be used, potentially along with eye-tracking glint data and outward-facing image data, for gaze detection, as well as for image stabilization to help correct for blur in images from the outward-facing image sensor(s) **1206**. The use of motion data may allow changes in gaze location to be tracked even if image data from outward-facing image sensor(s) **1206** cannot be resolved.

In addition, motion sensors **1218**, as well as microphone(s) **1208** and gaze detection subsystem **1210**, also may be employed as user input devices, such that a user may interact with the display system **1200** via gestures of the eye, neck and/or head, as well as via verbal commands in some cases. It may be understood that sensors illustrated in FIGS. **12** and **13** and described in the accompanying text are included for the purpose of example and are not intended to be limiting in any manner, as any other suitable sensors and/or combination of sensors may be utilized to meet the needs of a particular implementation of an augmented reality HMD device. For examples, biometric sensors (e.g., for detecting heart and respiration rates, blood pressure, brain activity, body temperature, etc.) or environmental sensors (e.g., for detecting temperature, humidity, elevation, UV (ultraviolet) light levels, etc.) may be utilized in some implementations.

The display system **1200** can further include a controller **1220** having a logic subsystem **1222** and a data storage subsystem **1224** in communication with the sensors, gaze detection subsystem **1210**, display subsystem **1204**, and/or other components through a communications subsystem **1226**. The communications subsystem **1226** can also facilitate the display system being operated in conjunction with remotely located resources, such as processing, storage, power, data, and services. That is, in some implementations, an HMD device can be operated as part of a system that can distribute resources and capabilities among different components and subsystems.

The storage subsystem **1224** may include instructions stored thereon that are executable by logic subsystem **1222**, for example, to receive and interpret inputs from the sensors, to identify location and movements of a user, to identify real objects using surface reconstruction and other techniques, and dim/fade the display based on distance to objects so as to enable the objects to be seen by the user, among other tasks.

The display system **1200** is configured with one or more audio transducers **1228** (e.g., speakers, earphones, etc.) so that audio can be utilized as part of an augmented reality experience. A power management subsystem **1230** may include one or more batteries **1232** and/or protection circuit modules (PCMs) and an associated charger interface **1234** and/or remote power interface for supplying power to components in the display system **1200**.

It may be appreciated that the depicted display devices **104** and **1200** are described for the purpose of example, and thus are not meant to be limiting. It is to be further understood that the display device may include additional and/or alternative sensors, cameras, microphones, input devices, output devices, etc. than those shown without departing from the scope of the present arrangement. Additionally, the physical configuration of a display device and its various sensors and subcomponents may take a variety of different forms without departing from the scope of the present arrangement.

FIGS. **14-18** show an illustrative alternative implementation for an augmented reality display system **1400** that may be used as a component of an HMD device. In this example, the system **1400** uses a see-through sealed visor **1402** that is configured to protect the internal optics assembly utilized for the see-through display subsystem. The visor **1402** is typically interfaced with other components of the HMD device (not shown) such as head mounting/retention systems and other subsystems including sensors, power management, controllers, etc., as illustratively described in conjunction with FIGS. **12** and **13**. Suitable interface elements (not shown) including snaps, bosses, screws and other fasteners, etc. may also be incorporated into the visor **1402**.

The visor includes see-through front and rear shields **1404** and **1406** respectively that can be molded using transparent materials to facilitate unobstructed vision to the optical displays and the surrounding real world environment. Treatments may be applied to the front and rear shields such as tinting, mirroring, anti-reflective, anti-fog, and other coatings, and various colors and finishes may also be utilized. The front and rear shields are affixed to a chassis **1505** as depicted in the partially exploded view in FIG. **15** in which a shield cover **1510** is shown as disassembled from the visor **1402**.

The sealed visor **1402** can physically protect sensitive internal components, including an optics display subassembly **1602** (shown in the disassembled view in FIG. **16**) when the HMD device is worn and used in operation and during normal handling for cleaning and the like. The visor **1402** can also protect the optics display subassembly **1602** from environmental elements and damage should the HMD device be dropped or bumped, impacted, etc. The optics display subassembly **1602** is mounted within the sealed visor in such a way that the shields do not contact the subassembly when deflected upon drop or impact.

As shown in FIGS. **16** and **18**, the rear shield **1406** is configured in an ergonomically correct form to interface with the user's nose and nose pads **1804** (FIG. **18**) and other comfort features can be included (e.g., molded-in and/or added-on as discrete components). The sealed visor **1402** can also incorporate some level of optical diopter curvature (i.e., eye prescription) within the molded shields in some cases.

FIG. **19** schematically shows a non-limiting embodiment of a computing system **1900** that can be used when implementing one or more of the configurations, arrangements, methods, or processes described above. The HMD device **104** may be one non-limiting example of computing system **1900**. The computing system **1900** is shown in simplified form. It may be understood that virtually any computer architecture may be used without departing from the scope of the present arrangement. In different embodiments, computing system **1900** may take the form of a display device, wearable computing device, mainframe computer, server computer, desktop computer, laptop computer, tablet computer, home-entertainment computer, network computing device, gaming device, mobile computing device, mobile communication device (e.g., smart phone), etc.

The computing system **1900** includes a logic subsystem **1902** and a storage subsystem **1904**. The computing system **1900** may optionally include a display subsystem **1906**, an input subsystem **1908**, a communication subsystem **1910**, and/or other components not shown in FIG. **19**.

The logic subsystem **1902** includes one or more physical devices configured to execute instructions. For example, the logic subsystem **1902** may be configured to execute instructions that are part of one or more applications, services, programs, routines, libraries, objects, components, data structures, or other logical constructs. Such instructions may be implemented to perform a task, implement a data type, transform the state of one or more components, or otherwise arrive at a desired result.

The logic subsystem **1902** may include one or more processors configured to execute software instructions. Additionally or alternatively, the logic subsystem **1902** may include one or more hardware or firmware logic machines configured to execute hardware or firmware instructions. The processors of the logic subsystem **1902** may be single-core or multi-core, and the programs executed thereon may be configured for sequential, parallel, or distributed processing. The logic subsystem **1902** may optionally include individual components that are distributed among two or more devices, which can be remotely located and/or configured for coordinated processing. Aspects of the logic subsystem **1902** may be virtualized and executed by remotely accessible, networked computing devices configured in a cloud-computing configuration.

The storage subsystem **1904** includes one or more physical devices configured to hold data and/or instructions executable by the logic subsystem **1902** to implement the methods and processes described herein. When such methods and processes are implemented, the state of the storage subsystem **1904** may be transformed—for example, to hold different data.

The storage subsystem **1904** may include removable media and/or built-in devices. The storage subsystem **1904** may include optical memory devices (e.g., CD (compact disc), DVD (digital versatile disc), HD-DVD (high definition DVD), Blu-ray disc, etc.), semiconductor memory devices (e.g., RAM (random access memory), ROM (read only memory), EPROM (erasable programmable ROM), EEPROM (electrically erasable ROM), etc.) and/or magnetic memory devices (e.g., hard-disk drive, floppy-disk drive, tape drive, MRAM (magneto-resistive RAM), etc.), among others. The storage subsystem **1904** may include volatile, nonvolatile, dynamic, static, read/write, read-only, random-access, sequential-access, location-addressable, file-addressable, and/or content-addressable devices.

It may be appreciated that the storage subsystem **1904** includes one or more physical devices, and excludes propagating signals per se. However, in some implementations, aspects of the instructions described herein may be propagated by a pure signal (e.g., an electromagnetic signal, an optical signal, etc.) using a communications medium, as opposed to being stored on a storage device. Furthermore, data and/or other forms of information pertaining to the present arrangement may be propagated by a pure signal.

In some embodiments, aspects of the logic subsystem **1902** and of the storage subsystem **1904** may be integrated together into one or more hardware-logic components through which the functionality described herein may be enacted. Such hardware-logic components may include field-programmable gate arrays (FPGAs), program- and application-specific integrated circuits (PASIC/ASICs), program- and application-specific standard products (PSSP/ASSPs), system-on-a-chip (SOC) systems, and complex programmable logic devices (CPLDs), for example.

When included, the display subsystem **1906** may be used to present a visual representation of data held by storage subsystem **1904**. This visual representation may take the form of a graphical user interface (GUI). As the present described methods and processes change the data held by the storage subsystem, and thus transform the state of the storage subsystem, the state of the display subsystem **1906** may likewise be transformed to visually represent changes in the underlying data. The display subsystem **1906** may include one or more display devices utilizing virtually any type of technology. Such display devices may be combined with logic subsystem **1902** and/or storage subsystem **1904** in a shared enclosure in some cases, or such display devices may be peripheral display devices in others.

When included, the input subsystem **1908** may include or interface with one or more user-input devices such as a keyboard, mouse, touch screen, or game controller. In some embodiments, the input subsystem may include or interface with selected natural user input (NUI) components. Such components may be integrated or peripheral, and the transduction and/or processing of input actions may be handled on- or off-board. Exemplary NUI components may include a microphone for speech and/or voice recognition; an infrared, color, stereoscopic, and/or depth camera for machine vision and/or gesture recognition; a head tracker, eye tracker, accelerometer, and/or gyroscope for motion detection and/or intent recognition; as well as electric-field sensing components for assessing brain activity.

When included, the communication subsystem **1910** may be configured to communicatively couple the computing system **1900** with one or more other computing devices. The communication subsystem **1910** may include wired and/or wireless communication devices compatible with one or more different communication protocols. As non-limiting examples, the communication subsystem may be configured for communication via a wireless telephone network, or a wired or wireless local- or wide-area network. In some embodiments, the communication subsystem may allow computing system **1900** to send and/or receive messages to and/or from other devices using a network such as the Internet.

Various exemplary embodiments of the present smart transparency are now presented by way of illustration and not as an exhaustive list of all embodiments. An example includes a method performed by a head mounted display (HMD) device employed by a user occupying a physical environment, the HMD device supporting rendering of a mixed reality or virtual reality environment that includes holographic objects, comprising: placing a fade volume around the user, the fade volume having a near shell that is proximate to the user and a far shell that is distal to the user; determining a location of a holographic object with respect to the near and far shells by tracking the user's location within the mixed reality or virtual reality environment; and rendering the holographic object with transparency when it is located between the near and far shells, the transparency increasing as the object becomes closer to the near shell.

In another example, the method further includes rendering the holographic object with full opacity when the holographic object is located beyond the far shell of the fade volume. In another example, the method further includes rendering the holographic object with full transparency when the holographic object intersects the near shell of the fade volume. In another example, the method further includes performing the rendering of the holographic object using alpha compositing and interpolating an alpha value based on a transparency curve that is established over a spatial distance between the near and far shells of the fade volume or performing the rendering of the holographic object using ordered dithering. In another example, the transparency curve is a linear curve and the alpha value is interpolated on a linear basis. In another example, the method further includes performing the alpha compositing for the holographic object on a per-pixel basis. In another example, the method further includes performing head tracking to determine a proximity of the fade volume to the holographic object. In another example, the head tracking utilizes a sensor package in the HMD device for generating depth data. In another example, the method further includes generating the depth data using one or more depth-from-stereo imaging analyses or using a depth sensor. In another example, the method further includes using the sensor package to determine a current height of the user's head above the ground of the physical environment. In another example, the method further includes sizing the fade volume according to the height of the user's head. In another example, the method further includes configuring a radius of the far shell to be between one and one-half and two and one-half times a radius of the near shell. In another example, the method further includes configuring the radius of the near shell to be approximately one-half meter and the radius of the far shell to be approximately one meter. In another example, the method further includes performing the transparent rendering of the holographic object to show a background of the mixed or virtual reality environment, the background including one or more of virtual ground, real ground, other holographic objects, or real objects. In another example, the method further includes configuring the near and far shells using one of cylinder, sphere, capsule, or non-radial volume. In another example, the method further includes configuring the near and far shells as concentrically aligned cylinders having different radii or as spheres having different radii that share a common center.

A further example includes a head mounted display (HMD) device operable by a user in a physical environment, comprising: one or more processors; a display having areas onto which a mixed reality or virtual reality environment is rendered to the user; a sensor package; and one or more memory devices storing computer-readable instructions which, when executed by the one or more processors, perform a method comprising the steps of: performing head tracking of the user within the physical environment using the sensor package, maintaining a holographic geometry including one or more holographic objects having known locations within the mixed reality or virtual reality environment, responsively to the head tracking, determining the user's location with respect to the holographic geometry, and rendering portions of the holographic geometry with transparency based on the user's location so that the rendered portions increase in transparency as the distance between the user's location and rendered portions decreases.

In another example, the HMD device further includes determining a ratio of distances of the rendered portions with respective near and far shells of a fade volume that is placed around the user and controlling alpha blending depending on the ratio on a per-pixel basis.

Another example includes one or more computer readable memories storing computer-executable instructions for rendering a mixed reality or virtual reality environment within a variable field of view of a head mounted display (HMD) device operating in a real world environment, the method comprising the steps of: configuring display optics incorporated into the HMD device for selectively rendering a holographic object with varying degrees of opacity; dynamically determining a location of a holographic object with respect to each of a near and a far threshold using sensors incorporated into the HMD device; setting opacity for a rendered holographic object to a maximum value when the holographic object is located beyond the far threshold; and when the holographic object is located between the near threshold and the far threshold, based on the location, setting opacity for a rendered holographic object from a range spanning a minimum value and the maximum value.

In a further example, the opacity is increased using one of alpha compositing or dithering as the distance between the holographic object and the near threshold increases and further including enclosing the user within a fade volume having a near shell that is located at the near threshold and a far shell that is located at the far threshold, the near and far shells being selected from one of cylinder, sphere, capsule, or non-radial volume.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

What is claimed:

1. A method performed by a head mounted display (HMD) device employed by a user occupying a physical environment, the HMD device having one or more processors and supporting rendering of a virtual reality environment that includes virtual objects, comprising:

placing, using the one or more processors coupled to the HMD device, a fade volume that surrounds the user, the fade volume having a near shell that is proximate to the user and a far shell that is distal to the user, in which the near shell is positioned a radial distance from the user such that the near shell is distinct from the user;

determining, using the one or more processors and one or more sensors coupled to the HMD device, a location of a virtual object with respect to the near and far shells by tracking the user's location within the virtual reality environment; and rendering, using the one or more processors, the virtual object with transparency when it is located between the near and far shells, the transparency increasing as the virtual object becomes closer to the near shell,

wherein the HMD device is configured to continuously render the virtual reality environment so that no part of the physical environment or the user is displayed on the HMD device.

2. The method of claim **1** further including rendering the virtual object with full opacity when the virtual object is located beyond the far shell of the fade volume.

3. The method of claim **1** further including rendering the virtual object with full transparency when the virtual object intersects the near shell of the fade volume.

4. The method of claim **1** further including performing the rendering of the virtual object using alpha compositing and interpolating an alpha value based on a transparency curve that is established over a spatial distance between the near and far shells of the fade volume or performing the rendering of the virtual object using ordered dithering.

5. The method of claim **4** in which the transparency curve is a linear curve and the alpha value is interpolated on a linear basis.

6. The method of claim **4** further including performing the alpha compositing for the virtual object on a per-pixel basis.

7. The method of claim **1** further including performing head tracking to determine a proximity of the fade volume to the virtual object.

8. The method of claim **7** in which the head tracking utilizes a sensor package in the HMD device for generating depth data.

9. The method of claim **8** further including generating the depth data using one or more depth-from-stereo imaging analyses or using a depth sensor.

10. The method of claim **8** further including using the sensor package to determine a current height of the user's head above the ground of the physical environment.

11. The method of claim **10** further including sizing the fade volume according to the height of the user's head.

12. The method of claim **1** further including configuring a radius of the far shell to be between one and one-half and two and one-half times a radius of the near shell.

13. The method of claim **12** further including configuring the radius of the near shell to be approximately one-half meter and the radius of the far shell to be approximately one meter.

14. The method of claim **1** further including performing the transparent rendering of the virtual object to show a background of the virtual reality environment, the background including one or more of virtual ground, or other virtual objects.

15. The method of claim **1** further including configuring the near and far shells using one of cylinder, sphere, capsule, or non-radial volume.

16. The method of claim **1** further including configuring the near and far shells as concentrically aligned cylinders having different radii or as spheres having different radii that share a common center.

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